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Hale, George Ellery

The national value of scientific research

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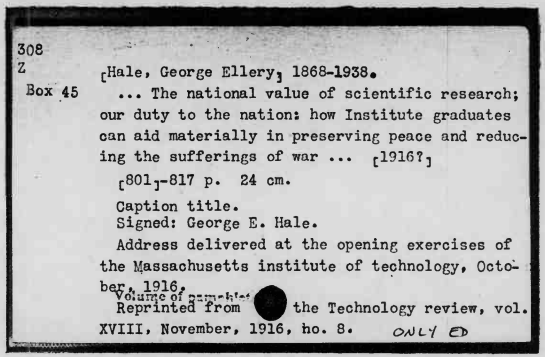

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THE NATIONAL VALUE OF SCIENTIFIC RESEARCH*

Our duty to the Nation—How Institute graduates can aid materially in preserving peace and reducing the sufferings of war

As we meet for the first time in this superb building, typical of the enlarged opportunities of the twentieth century, our thoughts go back to William Barton Rogers, founder and first President of the Institute. Combining in exceptional degree the appreciation of research and the constructive imagination of the man of science with the public spirit and the long vision of the statesman, he understood in the midst of the Civil War the deeper needs of the United States. Today, under the sharp demands of another and greater war, all countries have been forced to recognize their dependence upon science.

Recruiting its ablest investigators from the laboratories of London and other centers, as well as from the halls of Oxford and Cambridge, the British nation has attacked with vigor and success the problems of war and industry which have suddenly pressed for solution. Their naval establishment, always of high efficiency, has attained a new pitch of perfection. Their airplanes, inferior at the outset to those of the Teutonic powers, now appear to be assuming the command of the air. Their dirigibles, if still outranked by the Zeppelins, are rapidly approaching the same level of excellence. All this has sprung from science, spurred into activity for national service, pressed forward by the same patriotism which has filled the trenches and manned the guns of the Grand Fleet. And if war now dominates the field in England and in France, there are men and organizations in both countries who recognize that

*Address delivered at the opening exercises of the Massachusetts Institute of Technology, October, 1916.

the greater trial may come later, when the united industries of Germany, surprisingly developed by scientific research, will fight a fierce industrial war in the markets of the world.

Under such conditions, which must affect our own industries in almost equal degree, it is interesting to examine the early records of the Institute, and to recall the words used by Rogers in his first project for the school. In a report entitled "Objects and Plan of an Institute of Technology," prepared in 1860, Rogers wrote as follows:

> To secure a steady prosperity in the midst of the busy inventions and rapidly expanding knowledge which mark the industrial pursuits in the leading European nations, we feel that it has become indispensable for us to provide, at least as effectually as they have done, such facilities for practical knowledge, and for the intelligent guidance of enterprise and labor, as may make our progress commensurate, step by step, with the advances of scientific and practical discoveries.

Going on to describe his plan for the Institute, he laid first emphasis upon a department which subsequently received far less attention than it deserved:

> Under the first of these characters,—that of a Society of Arts,—the Institute of Technology would form itself into a department of investigation and publication, intended to promote research in connection with industrial science. . . .

The chief functions were to be performed by "the Committees of Arts, designed to form in a large measure the working power of the Institute." These were to

> be charged with the consideration of all questions and interests relating to the several branches which may be brought to the notice of the Institute and be empowered or required to report their suggestions to the general meeting. It should also be their province to propose subjects for investigation in their respective departments, to recommend experiments and trials of processes and machinery, and to designate such inventions or improvements as may be deemed worthy of special commendation or honorary reward.

As for Rogers' attitude toward pure science:

> We read in the history of social progress ample proofs that the abstract studies and researches of the philosopher are often the most beneficent sources of practical discovery and improvement.

And in his last address to the Institute:

> Formerly, a wide separation existed between theory and practice; now, in every fabric that is made, in every structure that is reared, they are closely united into one interlocking system; the practical is based upon the scientific, and the scientific is solidly built upon the practical.

Nov 19, 1917 AET

In the first period of the Institute's history, its work has consisted very largely of instruction, though investigation has become an increasingly prominent activity since the establishment by Dr. Noyes in 1903 of the Research Laboratory of Physical Chemistry. This laboratory, with those of industrial chemistry, sewage and sanitation, electrical engineering, aeronautics, gas engineering, etc., have not only advanced science and engineering through research, but have stimulated instruction by rendering visible to all students the daily growth of knowledge. May we not hope, now that the material needs of the Institute have been so largely met by the provision of this great group of buildings and by large additions to the endowment, that these laboratories may be more adequately supported, and that research may at last be raised to the high place which Rogers, with characteristic insight, felt that it should occupy? And may we not expect that pure science, which has advanced in this respect less rapidly than the industrial arts, will be recognized at its true value as the foundation stone of the Institute, and be permitted to assume equal importance in the research laboratory, as well as in the curriculum? Only thus can the highest success be attained.

It is a satisfaction to find the true significance of pure science widely proclaimed from the walls of these buildings, where the great names of Aristotle, Archimedes, Leonardo da Vinci, Copernicus, Newton, Lavoisier, Franklin, Faraday, Darwin, and Pasteur, flanked by many lesser ones, tell a tale that needs no comment.

William Barton Rogers, President of the Institute, was also president of the National Academy of Sciences, which dates, like the Institute itself, from the troubled year of 1863. Benefits similar to those which the Institute, chiefly by research, was to confer upon those who came within its circle, the Academy was intended to render to the national government. Constituted of the fifty leading representatives of the science and engineering of the day, the Academy received its federal charter from the hands of President Lincoln while the war was still in progress. This charter provides that

> the Academy shall, whenever called upon by any department of the Government, investigate, examine, experiment, and report upon any subject of science or art. . . . (Act of Congress, approved March 3, 1863.)

Under this provision, the Academy has been repeatedly asked to

advise the President, both Houses of Congress, and the heads of governmental departments. A few of these cases are cited below:

(1) Committees appointed in accordance with Acts of Congress:
- 1871. On the Transit of Venus.
- 1872. On Preparing Instructions for the *Polaris* Expedition.
- 1878. On a Plan for Surveying and Mapping the Territory of the United States.
- 1879. On a National Board of Health.
- 1894. To Prescribe and Publish Specifications for the Practical Application of the Definition of the Ampere and Volt.
- 1908. On the Method and Expense of Conducting Scientific Work under the Government.

(2) Committees appointed at the request of Joint Commissions and Committees of Congress:
- 1884. On the Signal Service of the Army, the Geological Survey, the Coast and Geodetic Survey, and the Hydrographic Office of the Navy Department.
- 1902. On the Establishment of a National Forest Reserve in the Southern Appalachians.

(3) Committees appointed at the request of the President of the United States:
- 1870. On the Protection of Coal Mines from Explosion by Means of Electricity.
- 1902. On Scientific Explorations in the Philippines.
- 1915. On the Slides of the Panama Canal.

Many of the minor questions of science formerly referred to the Academy, now go more appropriately to the various scientific bureaus which have been established by the government in recent years. Large problems arise from time to time, however, transcending the scope of any government bureau, and calling for the exercise of functions as broad as science itself. Such a case is represented by the establishment of the National Research Council. The immediate need for this body was indicated by the demands which the war has thrown upon the scientific men of other nations.

The individualistic tendencies of science in England are notably illustrated by the lives of Darwin and Faraday. Sprung respectively from the upper and the lower social strata, their careers were alike free from the influence of the schools. Both worked as individuals, unaided by organized effort; and both are typical of that marvelous succession of original thinkers and creators which Britain has given and still gives to the world. Her contribution to science is sufficiently indicated by the fact that out of the ten greatest names on the walls of the Institute, three—Newton, Faraday, and Darwin—are British.

But the slowness of England in calling science to her assistance in the present war is not chargeable to her investigators, nor to the great national societies which represent them. They saw from the outset the mistakes which had been made through the neglect of science by the government, and brought pressure to bear to remedy them. The fine flavor of classicism may be congenial to diplomacy, but under modern conditions of warfare the simple facts of science can be ignored only at heavy cost to the nation. Necessity, sharp and decisive, forced this view upon the government, and the men of science were at length called to the aid of the state. We shall see in the sequel what service they have rendered. For the moment let us return to our own province.

This war has proved, if proof were needed, that the predatory instincts of mediaeval times have not yet vanished from the world. Nations still exist whose policy of cold-blooded aggression knows no bounds except those set by expediency. When it seems reasonably safe to strike, they do not hesitate to annihilate everything that obstructs their path of conquest.

Under such conditions there is but one thing for possible victims to do. No sane man walks unprotected through the lion-haunted territory of British East Africa. The penalty for doing so has been vividly protrayed in Colonel Patterson's "Man Eaters of Tsavo." By the same token, no sane nation will remain unguarded, least of all a nation rich beyond all others and irrevocably committed to the aggressive dictum of the Monroe Doctrine. We have chosen to demand, and we have repeatedly proclaimed in no uncertain tones, that no European nation shall acquire a foot of territory in this hemisphere, even if it be more remote from us than Europe itself. Are we prepared to enforce this demand?

Believing it to be the duty of men of science to assist by every feasible means in strengthening the national defense, the National Academy of Sciences volunteered its services to the President on

the occasion of its annual meeting last April. Its purpose in doing so was not merely as a measure of military preparedness, but in recognition of the fact that the future welfare as well as the security of the nation depends in large measure upon its attitude toward science. Indeed, the words of Rogers, quoted at the opening of this address, admirably express the existing demand: "To secure a steady prosperity in the midst of the busy inventions and the rapidly expanding knowledge" of the European nations, we must utilize, as they are doing, "the advances of scientific and practical discovery." And in doing so, we must not always fix immediate commercial applicability as the criterion of successful research, but remember that "the abstract studies and researches of the philosopher are often the most beneficient sources of practical discovery and improvement." Thus we may extend to the needs of the nation the maxims applied by Rogers to the Institute of Technology.

The request of the President, addressed to the delegation which conveyed to him the offer of the Academy, called for immediate and vigorous action. He expressed the desire that the Academy should coördinate the scientific resources of the country and secure the coöperation of the many industries by which they are represented. And in doing so, he recognized and indicated the broad scope of the undertaking thus initiated.

An organizing committee, appointed forthwith, lost no time in beginning work. After securing cordial assurances of coöperation and support from the heads of government departments, scientific bureaus, national scientific and engineering societies, educational and research institutions, and industrial research laboratories, a plan of organization was formulated and laid before the council of the Academy on June 19. This plan recommended the establishment of a National Research Council, so constituted as to recognize and utilize scientific research in every field. It was seen from the outset that the activities of the council should not be confined to the promotion of researches bearing directly upon military problems, but that true preparedness would best result from the encouragement of every form of investigation, whether for military and industrial application, or for the advancement of knowledge without regard to its immediate practical bearing. The scheme of organization must be broad enough to secure the coöperation of all important agencies in accomplishing this result.

After considering a variety of plans, the Organizing Committee presented to the Council of the Academy the following recommendations:

That there be formed a National Research Council, whose purpose shall be to bring into coöperation existing governmental, educational, industrial, and other research organizations with the object of encouraging the investigation of natural phenomena, the increased use of scientific research in the development of American industries, the employment of scientific methods in strengthening the national defense, and such other applications of science as will promote the national security and welfare.

That the council be composed of leading American investigators and engineers, representing the army, navy, Smithsonian Institution, and various scientific bureaus of the government; educational institutions and research endowments; and the research divisions of industrial and manufacturing establishments.

That, in order to secure a thoroughly representative body, the members of the council be chosen in consultation with the Presidents of the American Association for the Advancement of Science, the American Philosophical Society, the American Academy of Arts and Sciences, the American Association of University Professors, and the Association of American Universities; that representatives of industrial research be selected with the advice of the Presidents of the American Society of Civil Engineers, the American Institute of Mining Engineers, the American Society of Mechanical Engineers, the American Society of Electrical Engineers, and the American Chemical Society, and that members of the cabinet be asked to name the representatives of the various departments of the government.

That research committees of two classes be appointed, as follows: (a) Central committees, representing various departments of science, comprised of leading authorities in each field, selected in consultation with the president of the corresponding national society. (b) Local committees in universities, colleges and other coöperating institutions engaged in scientific research.

The Organizing Committee also recommended the following plan of procedure, subject to such modifications as the National Research Council may deem desirable:

(1) The preparation of a national inventory of equipment for research, of the men engaged in it, and of the lines of investigation pursued in coöperating government bureaus, educational institutions, research foundations, and industrial research laboratories; this inventory to be prepared in harmony with any general plan adopted by the proposed Government Council of National Defense.

(2) The preparation of reports by special committees, suggesting important research problems and favorable opportunities for research in various departments of science.

(3) The promotion of coöperation in research, with the object of securing increased efficiency; but with careful avoidance of any hampering control or interference with individual freedom and initiative.

(4) Coöperation with educational institutions, by supporting their efforts to secure larger funds and more favorable conditions for the pursuit of research and for the training of students in the methods and spirit of investigation.

(5) Coöperation with research foundations and other agencies desiring to secure a more effective use of funds available for investigation.

(6) The encouragement in coöperating laboratories of researches designed to strengthen the national defense and to render the United States independent of foreign sources of supply liable to be affected by war.

The Council of the Academy voted to accept the proposals of the Organizing Committee, and instructed it to proceed with the formation of the National Research Council in accordance with the plan recommended.

The endorsement of the President of the United States and the authority to secure the appointment of government representatives, is conveyed in the following letter to the President of the Academy:

WASHINGTON, D. C., July 24, 1916.

DR. WILLIAM H. WELCH,
President of the National Academy of Sciences, Baltimore, Md.

My Dear Dr. Welch:

I want to tell you with what gratification I have received the preliminary report of the National Research Council, which was formed at my request under the National Academy of Sciences. The outline of work there set forth and the evidences of remarkable progress towards the accomplishment of the object of the council are indeed gratifying. May I not take this occasion to say that the departments of the government are ready to coöperate in every way that may be required, and that the heads of the departments most immediately concerned are now, at my request, actively engaged in considering the best methods of coöperation?

Representatives of government bureaus will be appointed as members of the Research Council as the council desires.

Cordially and sincerely yours,

(Signed) WOODROW WILSON.

On August 5, with the assent of the heads of the several executive departments, the President appointed nine representatives of the government as members of the Research Council. He has since appointed two additional members from the navy department at the request of the chairman of the council, and will appoint others as the needs of the work may require.

In a large undertaking of this nature, it is necessary to have the coöperation of other academies and societies, both general and special, which are concerned with the development of scientific and engineering research. It is a satisfaction to state that the most cordial assurance of coöperation has been received from all

sides. The following resolutions, adopted by the Engineering Foundation, which is administered by the four great national engineering societies having an aggregate membership of thirty thousand, are typical of those subsequently adopted by the American Philosophical Society, the Marine Biological Laboratory at Woods Hole, the Franklin Institute, and other organizations:

WHEREAS: The National Academy of Sciences of the United States of America has taken the initiative in bringing into coöperation existing governmental, educational, industrial and other research organizations with the object of encouraging the investigation of natural phenomena, the application of scientific principles in American industries, the employment of science in the national defense, and such other objects as will promote the national welfare, and

WHEREAS: These objects are among the objects for which the Engineering Foundation was created. Now, therefore, be it

Resolved, That the Engineering Foundation hereby registers its approval of the coördination and federation of the research agencies of the country undertaken by the National Academy of Sciences and expresses its willingness to join with and assist the National Academy in accomplishing the above federation.

The Engineering Foundation has also voted to apply its entire income for the current year (including a special gift of $5,000 for this purpose from its founder, Mr. Ambrose Swasey) toward the expenses of organization, to give the services of its secretary, and to provide a New York office for the National Research Council in the United Engineering Societies Building.

In addition to the American Association for the Advancement of Science, and the other bodies dealing with science as a whole which have already been mentioned, the special societies have shown an equal desire to coöperate with the council. In organizing committees dealing with questions of mathematics, physics, chemistry or any other department of science, the National Research Council has adopted the general policy of inviting the leading national society in that field to join with it in choosing the necessary committee, and in promoting its work. For example, in the case of the Committee on Nitrate Supply and the Central Chemistry Committee (which is organizing research in various branches of chemistry), the American Chemical Society is acting jointly with the National Research Council.

As already indicated, the work of the National Research Council involves the promotion of scientific research under three chief categories: the strengthening of the national defense, the development of American industries, and the advancement of knowledge.

In the first two of these fields, we may profit by a brief survey of the work which is now being done abroad by investigators engaged in the solution of problems raised by the war.

I have just returned from a short trip to England and France, where I went in company with Dr. William H. Welch, President of the National Academy, to learn how men of science can be of the most effective service under war conditions. The contrast with what I observed during a visit to Europe three years ago is a striking one. At that time the International Association of Academies, of which the National Academy of Science is the American representative, was holding its triennial meeting at St. Petersburg. For the delegates present national boundaries had ceased to exist, and the leaders of science from England, France, Germany, Russia, Italy, Holland, and other great nations were engaged in the consideration of the best means of promoting international coöperation in scientific research. Important projects for the development of the International Association of Academies, which might have led to a large extension of its activities, were under consideration. Berlin was selected as the next meeting place, and under normal conditions the triennial meeting would have been held there last May. But the war intervened. The men who were working together for the promotion of international science have necessarily turned their attention toward national problems, which will occupy their minds until the war ends. But not one of them has forgotten that science is after all an international matter, which should be promoted again from this point of view as soon as conditions permit. In spite of the narrowness and bitterness which a few representatives of science have shown, the great majority may be counted upon to exert their best influence in the future to secure a resumption of international relations as soon as circumstances may render them practicable.

The devotion to pure and applied science which the men of science and the engineers of all countries have shown in the past, is fully equalled by the enthusiasm with which they have thrown themselves into the solution of war problems. Recognizing, as they do, that their obligation to the state is fully equal to that of the men who have gone into the trenches, they have gladly put aside their ordinary pursuits for the purpose of concentrating their attention upon problems of national importance. The leaders in England are such men as Lord Rayleigh, Sir Joseph Thomson,

and Professor Arthur Schuster, all well known as physicists, and as leading officers of the Royal Society. Associated with them are many eminent investigators in various fields of science, such as Sir Ernest Rutherford, Professor Bragg, Sir Charles Parsons, Professor Starling, Sir Robert Hadfield, Sir Almroth Wright, and others as well known. In France we found an equally distinguished group, under the immediate direction of M. Painlevé, the eminent mathematician, now minister of public instruction. Associated with him in charge of the work of research are M. Borel and M. Perrin, distinguished in the fields of mathematics and physics. With them I found a group of investigators whom I have known for many years, including engineers, astronomers, physicists, mathematicians, chemists, physiologists, and men in other fields who have been gathered together from all parts of France. Thus M. Fabry has come from the University of Marseilles, M. Chrétien from the Nice Observatory, others from various centers of research in the provinces. To you who are familiar with the methods of research in pure science and engineering, it is easy to understand how these men have been able to drop their investigations in the observatory and laboratory, and turn their attention toward the solution of war problems. To the general public, which does not recognize that the astronomer is frequently engaged in investigations with the electric furnace or other apparatus closely similar to that employed in the manufacture of nitric acid or other explosives, or for the solution of other military and industrial problems, such a metamorphosis may be rather surprising. But experience has shown how readily the investigator can adapt himself to the solution of the problems which the exigencies of the moment may have thrust before him.

Thus we find Count de la Baume Pluvinel, the well known French astronomer, inventing an induction device which I saw in use at the hospitals at the front for finding pieces of shrapnel in the body. M. Chrétien is working on theoretical problems connected with the development of airplanes. Count de Notlys, whom I met in Dr. Carrel's hospital at Compeigne, has worked out a formula by which the time of healing of wounds can be predicted with great accuracy. The Duc de Broglie is busily engaged with naval problems. And so I might go on through a long list of other cases. I have particularly mentioned the work of three members of the old aristocracy, to indicate how heartily they have thrown themselves into the

task of defending the republic. This is merely a single illustration of how magnificently all elements in France have united for the common cause.

If time permitted, I might give you many illustrations from England of the similar work in progress there. I was naturally careful to avoid inquiring into any war secrets, regarding which I was not concerned. My object was to learn how engineers and men of science, with their minds open to the possibilities of improvements through research, can be of service to their country. Perhaps some illustrations which Sir Robert Hadfield, head of the great steel works at Sheffield, was kind enough to give me may prove of interest to this audience.

Not many years ago, when the perennial race between armor plate and projectiles was already well advanced, the case for the projectiles appeared to be a hopeless one. When fired from the most powerful gun, its hardened steel point merely splintered against the armor plate, and wholly refused to penetrate. Armor plate, as you doubtless know, is hardened only on its front surface. One day, on the proving grounds, a piece of armor was by chance set up in the wrong position; that is to say, its soft back was accidentally turned toward the gun. Greatly to the surprise of the observers, the projectile easily penetrated the plate. After it had been found that this could be repeated indefinitely, it occurred to some one to cover the hardened point of a steel projectile with a soft steel cap. When this was fired against the hardened steel face of armor plate the projectile passed through without difficulty, leaving fragments of the soft steel cap behind it.

This single illustration is typical of the innumerable opportunities for advance in every department of pure and applied science. Every student and graduate of the Institute, in time of war, would certainly wish to make the best contribution of which he is capable toward the defense of his country. But the most valuable assistance can be given now, in a time of peace. If weak and unprepared, we are liable to be attacked by any aggressive power that may covet our territory or that of our neighbors in this hemisphere. But if we solve some of the fundamental problems of preparedness, we are less likely to be molested, less exposed to crippling losses in case war should come. Thus mathematicians, chemists, physicists, geologists, biologists and engineers in every field can aid materially in preserving peace and in reducing the sufferings of possible war.

But how, you may ask, may they lend a hand? The answer is easy. Few of the problems to be solved are of a strictly military character. Take, for example, one which has been the subject of an exhaustive investigation by the National Research Council. At the request of the Secretary of War a strong committee, including in its membership three prominent representatives of the Institute, Dr. Noyes, '86 (Chairman), Dr. Whitney, '90, and Dr. Elihu Thomson of the Corporation, is preparing a report on the best utilization of the twenty million dollars appropriated by Congress for the fixation of nitrogen. From a military standpoint this matter is fundamental, as nitric acid enters into the manufacture of all high explosives. But in times of peace nitrates are equally important for the fertilization of the soil. The wise use of this appropriation is thus a question of great national significance, as it is well known that the yield of our farms could be enormously increased if an abundance of cheap fertilizer were available.

The Committee on Nitrate Supply has been fortunate in securing the cordial coöperation of many leading authorities and manufacturers, who have freely supplied information respecting the various processes. While some of these processes are in commercial use, the opinion is unanimous that through scientific research any existing process could be very materially improved. Specific investigations on catalytic agents and on many other factors, chemical and physical, which enter into the various processes, can be suggested by Dr. Noyes to any capable investigator who is prepared to deal with the subject. Research of this kind represents the best form of preparedness, applying equally to war or peace.

Sir Robert Hadfield's discovery of manganese steel, now so effectively employed for the helmets demanded by trench warfare, is another illustration of what can be accomplished by research. It was known that by adding 2 or 3 per cent. of manganese to iron, a very brittle alloy resulted. Sir Robert increased the proportion to about 14 per cent., and was rewarded by the production of a remarkable non-magnetic substance, of extraordinary toughness, which has found hundreds of applications in the arts. Similarly he produced his valuable low-hysteresis steel, employed so widely in electric transformers, by the use of a small percentage of selenium.

In the field of alloys alone the opportunities for progress are limitless. Our government is about to build rigid dirigibles, and

must have the lightest and stiffest skeleton bodies that can be constructed. Here is a chance for the experimenter. Germany has made great progress in this direction, and England has also accomplished much since the beginning of the war. But the field is still open, as the ideal alloy is yet to be produced.

The whole department of aeronautics is a fascinating one to the investigator. The Institute, thanks to the gift of Henry Morss, has set an example here which should be widely followed by other educational institutions. Through the provision of a wind-tunnel, with suitable auxiliary apparatus, valuable experimental work has been done by Lieutenant Hunsaker and by his successor, Lieutenant Alex. Klemin. In this connection the important part played by the mathematical physicist is admirably shown by the theoretical researches of Dr. E. B. Wilson.

At the request of Colonel Squier, chief of aviation, a member of the National Research Council, the council will coöperate with the National Advisory Committee on Aeronautics in promoting the investigation of aeronautical problems in educational institutions. Here again, it will be observed, the work accomplished will be no less useful in peace than in war. The council will soon publish a list of problems, to be prepared by Colonel Squier. This will prove of value to all who wish to engage in aeronautical research.

I might go on to mention the investigations which press for solution in the fields of ship design, steam and internal combustion engineering, preventive medicine, and in many other departments. But the cases I have cited will suffice to illustrate the nature of the work in view. Every Institute man will recognize from what has been said how closely some phase of this broad work must be related to his own daily occupations. He can assist in many ways: by taking part personally, or through associates or students, in some research which will be of service in strengthening the national defense; by aiding to secure a wider public recognition of the importance of science and especially of research in advancing our industries; by increased use of research in developing his own business, following the example of leading corporations; by gifts for the support of industrial research or research in pure science at the Institute or elsewhere; by the establishment of a Research Fellowship at the Institute, either in pure science or for industrial problems, following the plan of the Mellon Institute or that of

Yale University;* by suggesting important research problems to the committees of the National Research Council.

Additional information may be obtained by addressing the secretary of the council, 33 West Thirty-ninth street, New York. We are organizing committees on mathematics, physics, chemistry, geology, geography, preventive medicine and various other branches of science, in coöperation with the national societies in these fields. We are also forming committees on engineering and industrial research, in conjunction with the Engineering Foundation, which is conducted under the auspices of the national engineering societies. Thus the Research Council will soon be in a position to offer practical suggestions to anyone who may desire them. Problems bearing on the national defense, formulated by Admiral Taylor, Colonel Squier, and other members of the military section of the council, will be ready for distribution in the near future.

Within the limits of a single address it would obviously be impossible to enumerate any considerable fraction of the industrial problems which call for research. Take the question of dyestuffs where, as in many other fields, we are largely dependent upon Germany. If the serious problem of meeting foreign competition were already solved on the manufacturing and commercial side, there would still remain a great amount of research to be done before the manufacture of certain dyes could begin. For in many instances the processes have not been worked out here. Their essential details are known only in Germany, and must be independently discovered through the researches of our own chemists.

Another important case is that of optical glass. Through the aid of government subsidies, the firm of Schott & Company in Jena long since developed a remarkable series of glasses for optical purposes. Suddenly deprived of these at the outbreak of the war, and compelled to provide optical glass in large quantities for field-glasses, gun-sights, periscopes, range-finders and other instruments, England was forced to take immediate action. A series of investigations, undertaken by Professor Jackson of Kings College, London, and Dr. Rosenhain of the National Physical Laboratory, has already led to excellent results, but much remains to be done. France, which manufactured more optical glass than England before the war, has also made great progress. In this

*An annual contribution for one or more years enables the Research Fellow to attack any problem the donor may wish to have solved.

country we should institute similar investigations, as this is a case, like that of nitrates or dyestuffs, where it is hazardous to be dependent upon foreign sources of supply.

Quite apart from war or its effects, the development of our industries through scientific research is of the greatest importance to the nation. The financial value of research is fully appreciated by our great corporations, which are held up by the British Advisory Council of Scientific and Industrial Research as examples which their manufacturers must follow if they would compete with us effectively. The American Telephone and Telegraph Company, the General Electric Company, and the Westinghouse Company, respectively represented on the National Research Council by Dr. Carty, Dr. Thomson and Dr. Whitney, and Dr. Skinner, have shown in their laboratories what progress can be made by industrial research. But it is especially significant to note the attitude of these industrial leaders toward research in pure science.

When inviting me to make this address, President Maclaurin particularly asked me to refer to the importance of pure science in the Institute. He recognizes fully, as President Rogers did so long ago, and as the industrial leaders I have just mentioned so emphatically point out today, that industrial progress must depend directly upon the progress of pure science. Many investigations may advantageously be undertaken with immediate practical ends in view. But to use a commercial criterion as a measure of the value of all research would be a fatal error, since it would inevitably result in the loss to the world of the greatest discoveries in science. Marconi's development of wireless telegraphy would not have been possible without the prior work of Hertz, the physicist, who detected in his laboratory the electric waves which Maxwell's mathematical investigations on the electromagnetic theory of light had led him to predict. Carty delights in telling how his marvelous feat of telephoning without wires from Washington to the Hawaiian Islands was the direct outcome of researches in pure physics, made without thought of application in the arts. Pasteur's great contributions to medicine were the result of his studies of the optical properties of the crystals of tartaric acid, undertaken for no other purpose than to advance our knowledge of physics and chemistry. Even a science like astronomy, so often looked upon as of merely theoretical interest, is of fundamental importance to human progress. Poincaré has explained, in his

book *La Valeur de la Science*, how the initiation of research in every field of knowledge was stimulated by the discoveries of the ancient astronomers, and how undeveloped all branches of science would still be if we lived in a world perpetually surrounded by clouds.

Thus any form of scientific research, whether for the advancement of knowledge, the development of our industries, or the strengthening of the national defense, should be recognized as a valuable service to the public. The appreciation of this view by President Rogers was a dominant factor in the establishment of the Institute. Here in these new laboratories, when scientific research has been developed as far as available funds will permit, and when the wisest balance has been established between pure science and its applications, the Institute will set an example which the entire country would do well to follow. Taken as it stands, the original plan of President Rogers for the Institute also serves to define many of the most important possibilities of the National Research Council. May we not count, therefore, upon a close coöperation between the Institute and the Council, in the hope that both may thus benefit in the advancement of their common aim—the larger utilization of science for the welfare of the nation?

GEORGE E. HALE, '90.

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